Exhibit A

P12595

Referee's Recommendation		For Local Operation Use
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Referee's Comments:

Ericsson Inc. Invention Disclosure Cover Form

1. Invention Title: An Enhanced Adaptive Frequency Allocation (Afa) Algorithm For Indoor Radio Base Station Systems

2. Disclosure Submitted by (Add additional sheets if more than three inventors):

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3. Important—For purposes of properly assigning any issued patent for this invention, please check which organization funded the work on this invention: ☐EUS/SC ☐ECS ☐RPRS ☒ERA (BMOA, BMOG, DWOS) ☐Global Resources (BRL) ☐Other (specify name)

4. Date invention conceived (mm/dd/yy): ▮▮▮ **5. Date invention reduced to practice:** ▮▮▮

6. Identify (including dates) any past or anticipated disclosure outside the company, such as publication, offer for sale, actual sale, discussions with business partners, etc.:

7. Invention made using government or non-Ericsson funding?: No

8. Present or proposed use of the invention (identify products and dates): GSM and TDMA indoor basestations

9. Identify related invention disclosures of which you are aware: (Ericsson Patent Application Control# P10508 -- filed in US, Argentina, & Chile)

10. Please attach to this cover form your invention disclosure, along with any other relevant documentation (see "IPR at RTP" Web site for additional information on writing disclosures).

The invention described in the attached invention disclosure is hereby submitted under my employment agreement with Ericsson Inc.

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An enhanced adaptive frequency allocation (AFA) algorithm for indoor radio base station systems

Abstract

This invention proposes an enhanced adaptive frequency allocation algorithm that can be used in an indoor radio base station system to effectively minimize the risk of increased call blocking probability due to the lack of frequencies with low interference. It could be especially useful for an indoor system in a severely interfered environment.

1. **What problem is solved by your invention? Describe generally the nature of your invention and what area of technology it addresses.**

The adaptive frequency allocation (AFA) is a dynamic channel allocation scheme that automatically finds and maintains a pool of least interfered frequencies, called **allocated frequencies**, that can be assigned both as control and traffic channels. AFA accomplishes this task by evaluating, in real-time, all frequencies in the entire frequency band the system operates on.

AFA has been successfully used in indoor base station systems such as in Ericsson Digital Wireless Office System (DWOS) which is a private radio system. AFA can also be applied in a public indoor base station system. One of the biggest advantages of AFA compared with a fixed channel allocation (FCA) scheme, where a fixed set of frequencies are assigned to individual cells, is that the tedious cell planning and parameter settings can be avoided.

AFA heavily relies on frequencies that have low interference from the outside macro/micro base stations, even during the busy hours. A frequency can have a low interference level if, for example, the closest cells that use the frequency in the outdoor system have a sufficiently large distance from the indoor system. Low interference on a certain frequency also occurs when the radio signal transmitted by the outdoor system has a large path loss due to the penetration through walls, floors, etc.

With the increasing tightening of the frequency reuse plan in the surrounding outdoor systems, however, more and more frequencies will be used in a closer distance to an indoor system. Depending on the indoor system's radio environment, there is an increasing risk of

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AFA having too few allocated frequencies to handle offered traffic and to maintain channel quality.

This invention proposes an enhancement to the existing AFA by utilizing the frequencies more effectively in the case where the number of allocated frequencies is too low. Section 2 briefly describes the existing AFA algorithm implemented in the Ericsson DWOS. Section 3 discusses the drawbacks of the existing AFA. In section 4, we describe the proposed AFA algorithm and summarize its benefits.

2. **How was this problem solved before (inside or outside Ericsson)? Cite any known inventions for which yours is a replacement.**

The AFA finds and maintains a pool of allocated frequencies that the radio control unit can assign to the incoming call requests and the handoff requests. The principle of the existing AFA (Ericsson Patent Application Control # P10508 filed in US) is depicted in Figure 1.
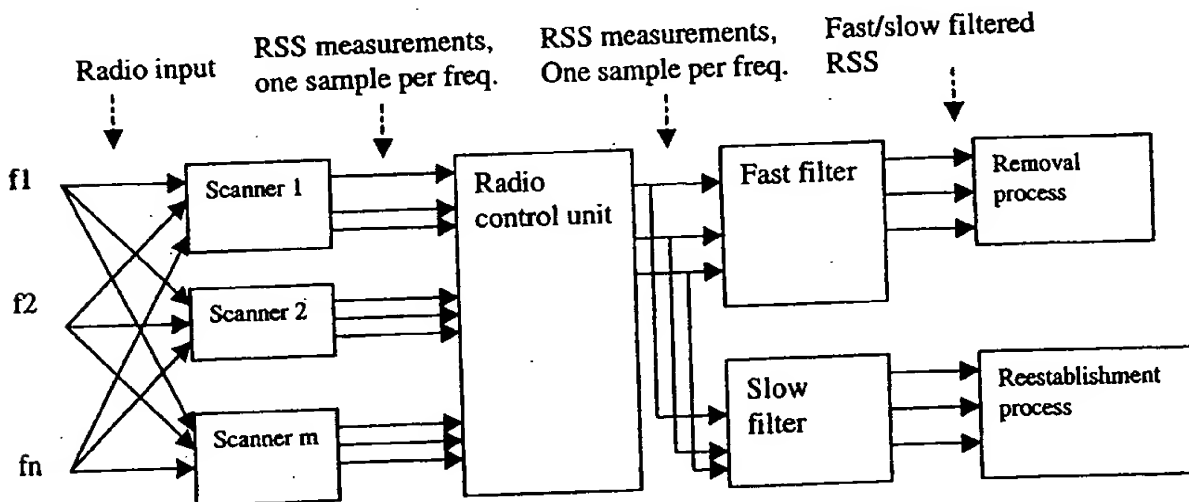

Figure 1: AFA data flow

The existing AFA uses dedicated radio scanners placed in different locations of the building to periodically measure the radio signal strength (RSS) of all frequencies. Each scanner includes one uplink receiver and two downlink receivers (for diversity). Every receiver in a

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scanner takes one RSS sample per frequency per scanning period so that there are three samples per frequency for every scanning period. The scanner only passes the maximum RSS sample per frequency to the radio control unit for processing. For each frequency, the radio control unit takes the maximum RSS sample out of the RSS samples from the multiple scanners. The radio control unit then feeds the RSS sample of each frequency to two low-pass filters to smooth out the random variations of the measured RSS due to fading. One fast filter applies a small time constant to produce a filtered RSS output, called **fast filtered RSS**, that reacts quickly to the new RSS measurement. The second slow filter uses a large time constant to generate filtered RSS output, called **slow filtered RSS**, that responses slowly to the new RSS measurement. The AFA algorithm consists of two processes, the **removal process** that removes the frequencies from the set of allocated frequencies based on the fast filtered RSS and the **reestablishment process** that reestablishes frequencies that are currently not allocated based on the **slow filtered RSS**.

In order to remove the interfered frequencies as soon as possible and to make the allocated frequencies stable, the removal process is executed much more frequently than the reestablishment process (see Figure 2). The time duration between two consecutive removal processes is called a **removal period** and the time duration between two reestablishment processes is called a **reestablishment period**. As can be seen in Figure 2, the reestablish period is much longer than the remove period.
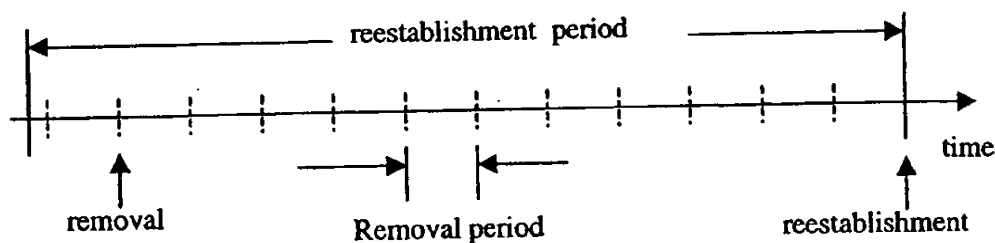

Figure 2: removal and reestablishment period

The AFA algorithm processes all frequencies, and the following frequency sets are defined:

(a) The **allocated set** contains the frequencies that the radio control unit can assign to the incoming call requests and the handoff requests. The operator can either use a set of

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manually selected frequencies as the allocated set or let AFA to automatically find an initial allocated set before user traffic is allowed to enter the system.

(b) The **interfered set** contains the frequencies that have a non-zero **residual penalty time**. AFA sets an **initial penalty time** for a frequency when it detects that fast filtered RSS of that frequency exceeds certain **interference thresholds.**

(c) The **useable set** contains the frequencies that have a zero penalty time. Note that the usable set contains the allocated set and the existing AFA can only reestablish frequencies from the usable set.

During each removal process, the existing AFA performs the following steps:

- Decrement the penalty time of frequencies with non-zero residual penalty time by the amount of a single removal period.

- Check, for each frequency, if the fast filtered RSS exceeds certain interference thresholds. If so, set the residual penalty time to the initial penalty time or the current residual penalty time whichever is larger.

- Remove any frequencies in the allocated set that have a non-zero residual penalty time.

The following changes take place after each removal process:

Zero, one or more frequencies are removed from the allocated set. This implies a corresponding increase of size of the interfered set.

The size of the usable set may decrease depending on how many frequencies have exceeded the interference thresholds.

During the reestablishment process, which occurs after C (C>>1) removal processes, AFA sorts all frequencies with zero penalty time according to their slow filter RSS and then selects N frequencies with the lowest slow filtered-RSS to be the proposed allocated set. Note that some frequencies in the proposed set may already be in the allocated set. In that case, these frequencies will stay in the allocated set because they belong to the N best frequencies in the useable set.

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AFA then compares the frequencies with the lowest slow filtered RSS in the proposed set, that are not already in the allocated set, with the frequencies that have the highest slow filtered RSS in the allocated set. If the former are sufficiently better based on a hystereisis then the two sets of frequencies are swapped. AFA limits the number if frequency swapped since the swapping can force intra radio head handoffs causing disturbance to the call processing.

3. What is drawback of the known method?
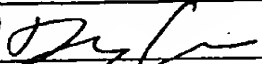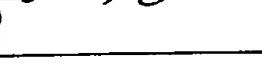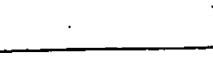
Using the existing AFA, the risk of system having too few allocated frequencies can be quite high in a high interference environment, especially when the AFA parameters are set such that:

- Interference thresholds are low.

- Penalty time is long.

- Reestablishment period is long compared with the removal period.

Using the existing AFA, the frequencies with a non-zero penalty time can not be used as allocated frequencies even when they have low interference. It would be very advantageous to utilize these frequencies in the case where the number of allocated frequencies becomes too low to handle the offered traffic.

Another drawback of the existing AFA is that the system waits too long for the next reestablishment process if the number of allocated frequencies is too low due to the long reestablishment period.

Figure 3 shows a possible variation of the size of the allocated set as removal and reestablishment processes are executed. Note that with each removal, the number of allocated frequencies either decreases or remains unchanged. In this example, the number of allocated frequencies is below the minimum size most of the time within a reestablishment period.

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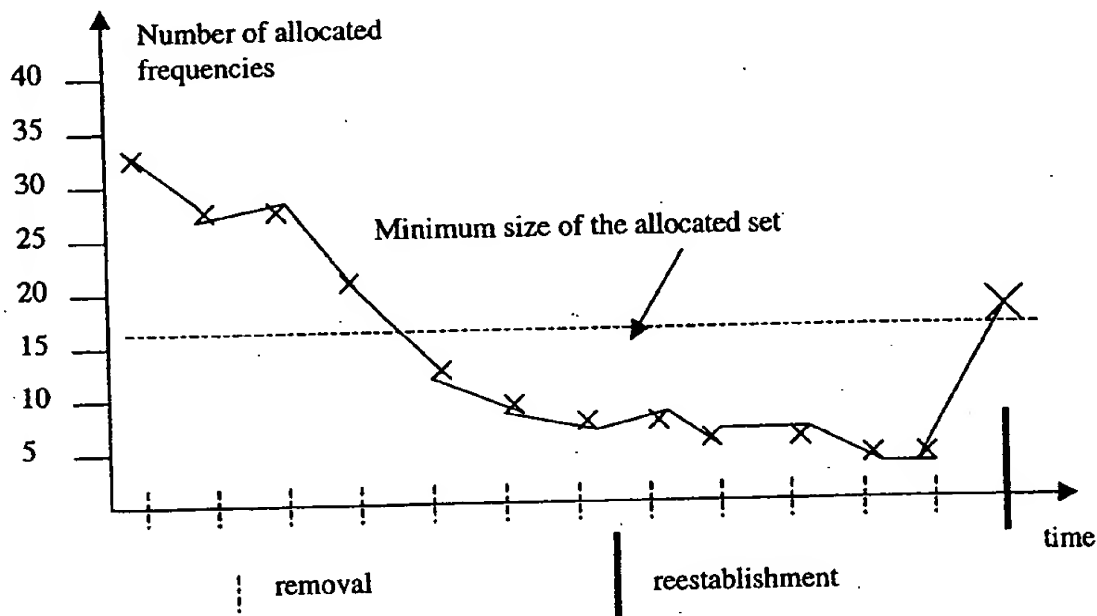| *Prepared* RT/EUS/GR Dayong Chen x26881		*Date* 10/09/00	*Rev* A	*EUS no. (For Patent Engineering Use Only)*
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Number of allocated frequencies

Figure 3: size of allocated set during a reestablishment period

4. **What is your invention and how is it better than those prior solutions? Describe in detail the structure and operation of your invention, including the features which make it advantageous over known inventions. Be specific in your description of how to make and use your invention. Attach drawings, flow charts, block diagrams, schematics, etc.**

This invention proposes a reestablishment process that can be triggered in each normal removal process but only if the number of allocated frequencies drops below a critical limit.

At every removal period:

Per form the following steps as in the existing AFA:

- Perform the same steps as in the existing AFA algorithm, i.e. decrement penalty time, check fast filtered RSS and remove any allocated frequencies with non-zero penalty time.

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- Now, check whether or not the number of frequencies in the allocated set N_A is greater than or equal to N_C:

$$N_A - N_C \geq 0 \qquad (1)$$

The value of N_C is selected such that having N_C frequencies in the allocated set is sufficient to meet the GoS (Grade of Service) requirement for the offered traffic during the peak hours.

- If condition (1) is true, no more action is needed and the removal process is complete. However, if $N_A - N_C < 0$ then the following steps are performed to reestablish frequencies.

The proposed steps for the enhanced AFA:

(a) Sort all frequencies based on their slow filtered RSS and then keep a maximum of N_1 frequencies that have the lowest slow filtered RSS. Also, all N_1 frequencies must satisfy (Figure 4):

$$RSS_i < L_{max} \qquad (2)$$

Here $i = 1,2,3,...N$, RSS_i is the slow filtered RSS of the i-th frequency and L_{max} is the maximum allowed interference. L_{max} can e.g. be set to the lowest interference threshold.

(b) Sort the N_1 frequencies according to their residual penalty time. Select N_2 out of N_1 frequencies with the smallest penalty time. Also, the N_2 frequencies must satisfy:

$$PT_i < T_{max} \qquad (3)$$

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Here PT_i is the residual penalty time of the i-th frequency and T_{max} is the maximum allowed residual penalty time (Figure 4). T_{max} can be set to e.g. 30% of the initial penalty time corresponding to the lowest interference threshold.

(c) Check for each of the N_2 frequencies if it is already in the allocated set. If not, reset the penalty time of that frequency to zero, if it is not already zero, and then add the frequency to the allocated set. Repeat this step until every selected frequency has been checked and possibly added to the allocated set.
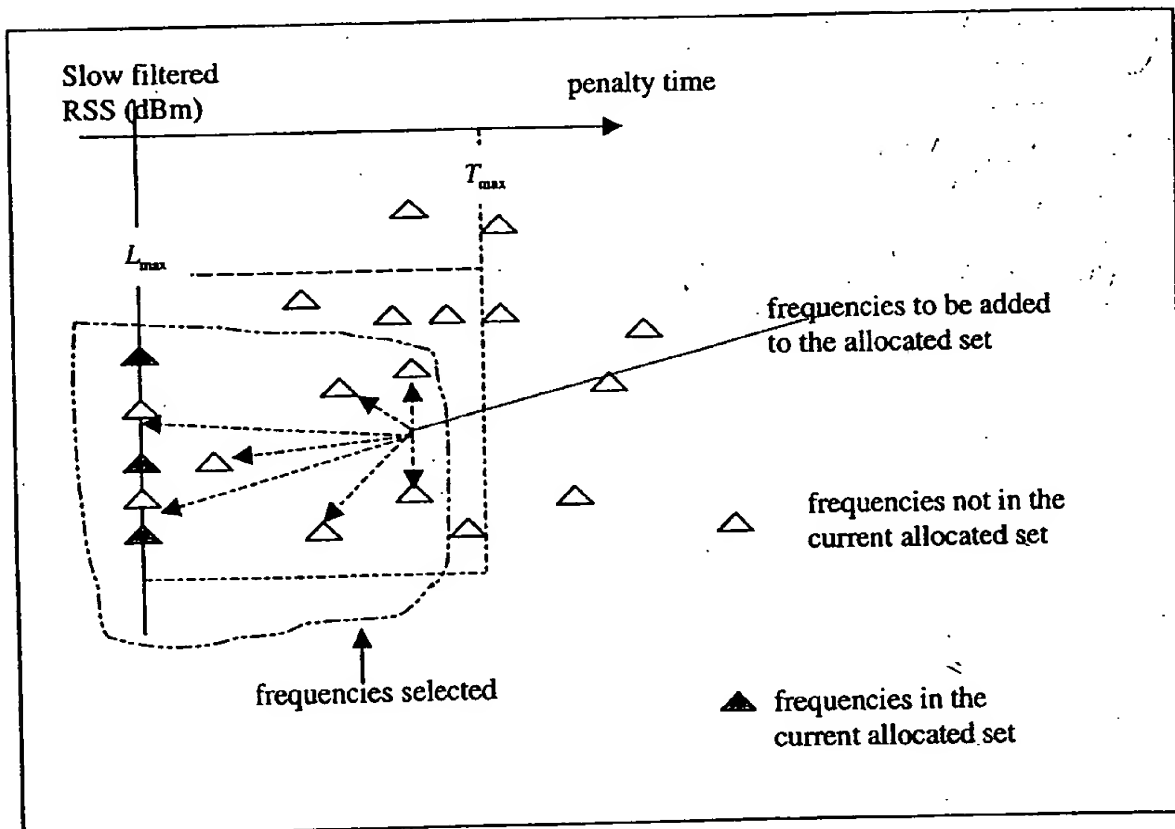

Figure 4: frequency selection in the new AFA algorithm

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The major advantages of this invention are summarized below:

- The risk of AFA having too few allocated frequencies is minimized because once the size of the allocated set drops below a critical level the proposed reestablishment process is executed with very short reaction time.

- If the size of the allocated set never drops below the critical level, the new AFA behaves exactly the same as the existing AFA.

- The frequencies are much better utilized when they are mostly needed, i.e. when the number of allocated frequencies is potentially too low to handle the offered traffic. In the existing AFA, frequencies can not be used as long as their penalty time has not reached zero even when they have low interference.

- The selection of the frequencies to be added is the optimum in the sense that the selected frequencies have the lowest slow filtered RSS as well as the lowest residual penalty time.

In Figure 5, a possible example shown. It is assumed that the interference situation is exactly the same as shown in Figure 3.

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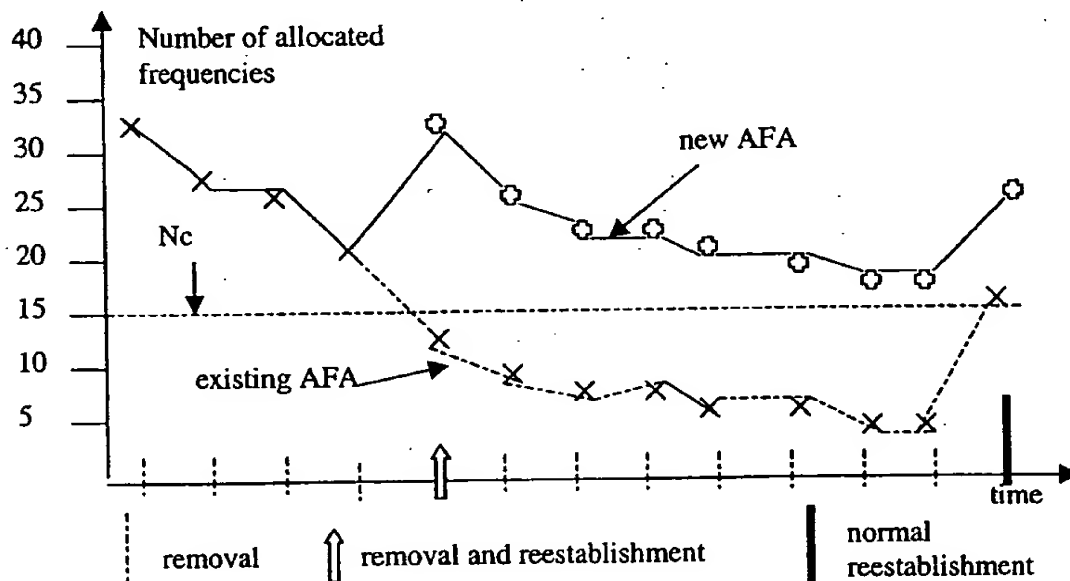| Prepared			Date	Rev	EUS no. (For Patent Engineering Use Only)
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Figure 5: size of allocated set using the existing and the new AFA algorithm

In Figure 5, on the 5th normal removal process, the number of allocated frequencies drops below Nc (=15 in this example). During the 5th removal process, the new AFA first performs the normal removal procedure. Since the number of allocated frequencies is below 15, the new AFA reestablishes frequencies using the proposed frequency selection. In the subsequent removal processes, the size of the allocated set never drops below 15 and these removal processes are exactly the same as in the existing AFA. Finally the normal reestablishment process increases size of the allocated set by another 10 frequencies. Using the new AFA, the system is able to maintain at least 15 frequencies all the times within the reestablishment period. In contrast, the size of the allocated set drops below 15 for most of the time within a reestablishment period if the existing AFA were used.

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